

CLAIMS

We/I claim:

1. A method of operating a fuel cell system to power a load, the method comprising:

supplying current to the load from at least one of a fuel cell stack and a battery electrically coupled in parallel with the fuel cell stack;

determining an operational condition of the battery;

determining an amount of deviation of the determined operational condition of the battery from a desired operational condition of the battery; and

for at least one reactant flow to at least a portion of the fuel cell stack, adjusting a partial pressure of the reactant flow based on the determined amount of deviation.

2. The method of claim 1 wherein determining an operational condition of the battery includes determining current flow into and out of the battery over a period of time.

3. The method of claim 1 wherein determining an amount of deviation of the determined operational condition of the battery from a desired operational condition of the battery includes integrating a difference between a defined desired nominal charge and current flows into and out of the battery over a period of time.

4. The method of claim 1 wherein determining an amount of deviation of the determined operational condition of the battery from a desired operational condition of the battery includes integrating a difference between a defined desired nominal charge and current flows into and out of the battery over a period of time, where the desired nominal charge is between approximately 75 percent and approximately 85 percent of a full charge for the battery.

5. The method of claim 1 wherein determining an operational condition of the battery includes determining a voltage across the battery.

6. The method of claim 1 wherein determining an amount of deviation of the determined operational condition of the battery from a desired battery operational condition includes comparing a determined battery charge to a defined desired nominal battery charge.

7. The method of claim 1 wherein adjusting a partial pressure of the reactant flow based on the determined amount of deviation includes adjusting a partial pressure of a flow of fuel to at least a portion of the fuel cell stack and adjusting a partial pressure of a flow of oxidant to at least the same portion of the fuel cell stack.

8. The method of claim 1, further comprising:
holding a pressure of the at least one reactant flow approximately constant while adjusting the partial pressure of the at least one reactant flow.

9. A method of operating a fuel cell system, comprising:
supplying current at a number of output terminals from at least one of a fuel cell stack and a battery electrically coupled in parallel with the fuel cell stack; and
adjusting a partial pressure of a reactant flow to at least a portion of the fuel cell stack to maintain a desired nominal charge on the battery.

10. The method of claim 9, further comprising:
determining a current flow to and from the battery; and
determining an amount of deviation of a charge of the battery from the desired nominal charge of the battery based on the determined current flow; and wherein adjusting a partial pressure of a reactant flow to at least a portion of the fuel cell stack to maintain a desired nominal charge on the battery includes adjusting the partial pressure of the reactant flow based on the determined amount of deviation.

11. The method of claim 9, further comprising:
determining a voltage across the battery; and

determining an amount of deviation of the voltage across the battery from a desired nominal voltage across the battery; and wherein adjusting a partial pressure of a reactant flow to at least a portion of the fuel cell stack to maintain a desired nominal charge of the battery includes adjusting the partial pressure of the reactant flow based on the determined amount of deviation.

12. The method of claim 9, further comprising:

holding a pressure of the at least one reactant flow approximately constant while adjusting the partial pressure of the at least one reactant flow.

13. A method of operating a fuel cell system, comprising:

supplying current at a number of output terminals from at least one of a fuel cell stack and a battery electrically coupled in parallel with the fuel cell stack;

determining a current flow to and from the battery;

determining an amount of deviation of a nominal charge of the battery from a defined desired nominal charge of the battery based on the determined current flow; and

adjusting a partial pressure of a reactant flow to at least a portion of the fuel cell stack in a mathematically defined relation to the determined amount of deviation.

14. The method of claim 13 wherein determining an amount of deviation of the determined current flow from a desired nominal charge of the battery includes integrating a difference between the desired nominal charge and the determined current flow into and out of the battery over a period of time.

15. The method of claim 13 wherein the desired nominal charge of the battery is between approximately 75% and approximately 95% percent of a full charge for the battery.

16. The method of claim 13 wherein the mathematically defined relation between the determined deviation and the partial pressure of the reactant flow is an inversely proportional relationship.

17. A method of operating a fuel cell system, comprising:
supplying current to a number of output terminals from at least one of a fuel cell stack and a battery electrically coupled in parallel with the fuel cell stack;
determining a voltage across the battery;
determining an amount of deviation of the determined voltage across the battery from a defined desired nominal voltage across the battery; and
adjusting a partial pressure of a reactant flow to at least a portion of the fuel cell stack in proportion to the determined amount of deviation.

18. The method of claim 17, further comprising:
holding a pressure of the at least one reactant flow approximately constant while adjusting the partial pressure of the at least one reactant flow.

19. The method of claim 17 wherein the battery includes a plurality of battery cells contained in a single enclosure.

20. The method of claim 17 wherein the battery includes a plurality of battery cells contained in a number of respective enclosures.

21. A fuel cell system for providing power to a load, comprising:
a fuel cell stack having a number of fuel cells;
a battery having a number of battery cells electrically couplable in parallel across the fuel cell stack;

a reactant delivery system for delivering reactant to the fuel cells, the reactant delivery system including at least a first control element adjustable to control a partial pressure in a flow of a reactant to at least some of the fuel cells; and

a control circuit coupled to receive signals corresponding to an operating condition of the battery and configured to determine a deviation of the operating condition of the battery from a desired operational condition of the battery based on the received signals, the control circuit further coupled to control the at least first control element based on the determined deviation.

22. The fuel cell system of claim 21, further comprising:

a current sensor coupled to measure a flow of current into and out of the battery and to provide the measured flow of current to the control circuit as the signals corresponding to the operating condition of the battery.

23. The fuel cell system of claim 21, further comprising:

a voltage sensor coupled to measure a voltage across the battery and to provide the measured voltage to the control circuit as the signals corresponding to the operating condition of the battery.

24. The fuel cell system of claim 21 wherein the control circuit comprises an integrator and a comparator.

25. The fuel cell system of claim 21 wherein the control circuit comprises an alternator controller.

26. The fuel cell system of claim 21 wherein the control circuit comprises a microprocessor.

27. The fuel cell system of claim 21 wherein the fuel cells and the battery cells are interconnected such that the battery cells are electrically coupled in parallel with respective sets of the fuel cells.

28. The fuel cell system of claim 21 wherein the control circuit is further configured to hold a pressure of the at least one reactant flow approximately constant controlling the at least first control element based on the determined deviation.

29. A fuel cell system for providing power, comprising:
a fuel cell stack having a number of fuel cells;
a battery having a number of battery cells, portions of the battery electrically couplable in parallel across respective portions of the fuel cell stack;
a reactant delivery system for delivering reactant to the fuel cells, the reactant delivery system including at least a first flow regulator adjustable to control a partial pressure in a flow of a reactant to at least some of the fuel cells to maintain a defined desired nominal charge of the battery.

30. The fuel cell system of claim 29, further comprising:
a control circuit coupled to receive signals corresponding to an operating condition of the battery and to provide a control signal to at least the first flow regulator to maintain the desired nominal charge of the battery.

31. The fuel cell system of claim 29, further comprising:
a control circuit coupled to receive signals corresponding to a flow of current to and from the battery and to provide a control signal to at least the first flow regulator mathematically related to a difference between a nominal battery charge determined from the received signals and the defined desired nominal charge of the battery.

32. The fuel cell system of claim 29, further comprising:

a control circuit coupled to receive signals corresponding to a voltage across the battery and to provide a control signal to at least the first flow regulator mathematically related to a difference between the voltage across the battery and a desired nominal voltage across the battery.

33. A fuel cell system for providing power, comprising:

a fuel cell stack having a number of fuel cells;

a battery electrically couplable in parallel across the fuel cell stack;

a reactant delivery system for delivering reactant to the fuel cells, the reactant delivery system including at least a first flow regulator adjustable to control a partial pressure in a flow of a reactant to at least some of the fuel cells; and

a control circuit coupled to receive signals corresponding to a flow of current to and from the battery and to provide a control signal to at least the first control element mathematically related to a difference between a defined desired charge on the battery and a nominal charge on the battery determined from the flow of current to and from the battery.

34. The fuel cell system of claim 33 wherein the control circuit comprises,

an integrator having an input and an output, the input coupled to receive the signals corresponding to the flow of current to and from the battery; and

a comparator having at least a first input and a second input, the first input coupled to the output of the integrator to receive an integration of the flow of current to and from the battery, the second input coupled to a reference for receiving a set point corresponding to the desired charge on the battery, and the output coupled to at least the first flow regulator of the reactant delivery system.

35. A fuel cell system for providing power, comprising:

a fuel cell stack having a number of fuel cells;

a battery electrically couplable in parallel across the fuel cell stack;

a reactant delivery system for delivering reactant to the fuel cells, the reactant delivery system including at least a first flow regulator adjustable to control a partial pressure in a flow of a reactant to at least some of the fuel cells; and

a control circuit coupled to receive signals corresponding to a voltage across the battery and to provide a control signal to at least the first control element mathematically related to a difference between the voltage across the battery and a defined desired voltage across the battery.

36. The fuel cell system of claim 35 wherein the control circuit comprises, a voltage regulator.

37. A method of operating a fuel cell system to power a load, the method comprising:

electrically coupling portions of a battery having a plurality of battery cells in parallel with portions of a fuel cell stack having a plurality of fuel cells; and
supplying current to the load from at least one of the fuel cell stack and the battery.

38. The method of claim 37, further comprising:

determining an operational condition of the battery;

determining an amount of deviation of the determined operational condition of the battery from a desired operational condition of the battery; and

for at least one reactant flow to at least a portion of the fuel cell stack, adjusting a partial pressure of the reactant flow based on the determined amount of deviation.

39. The method of claim 37, further comprising:

determining current flow into and out of the battery over a period of time;

integrating a difference between a defined desired nominal charge and current flows into and out of the battery over a period of time; and

for at least one reactant flow to at least a portion of the fuel cell stack, adjusting a partial pressure of the reactant flow based on the integrated difference.

40. The method of claim 37, further comprising:
determining a voltage across the battery;
comparing a determined battery charge to a defined desired nominal battery charge; and

for at least one reactant flow to at least a portion of the fuel cell stack, adjusting a partial pressure of the reactant flow based on the comparison.

41. A fuel cell system for providing power to a load, comprising:
a fuel cell stack having a number of fuel cells;
a battery having a number of battery cells, groups of the battery cells electrically couplable in parallel across respective groups of the fuel cells; and
a reactant delivery system for delivering reactant to the fuel cells, the reactant delivery system including at least a first control element adjustable to control a partial pressure in a flow of a reactant to at least some of the fuel cells.

42. The fuel cell system of claim 41, further comprising:
a control circuit coupled to receive signals corresponding to an operating condition of the battery and configured to determine a deviation of the operating condition of the battery from a desired operational condition of the battery based on the received signals, the control circuit further coupled to control the at least first control element based on the determined deviation.

43. The fuel cell system of claim 41 wherein the groups of battery cells each include a single one of the battery cells.

44. The fuel cell system of claim 41 wherein the groups of fuel cells each include a single one of the fuel cells.

45. The fuel cell system of claim 41 wherein the number of fuel cells included in each of the groups of fuel cells is greater than the number of battery cells included in the respective group of battery cells.

46. The fuel cell system of claim 41, further comprising:
a super capacitance electrically coupled in parallel across the battery.

47. The fuel cell system of claim 41, further comprising:
a control circuit coupled to receive signals corresponding to an operating condition of the battery and to provide a control signal to at least the first flow regulator to maintain the desired nominal charge of the battery.

48. The fuel cell system of claim 41, further comprising:
a control circuit coupled to receive signals corresponding to a flow of current to and from the battery and to provide a control signal to at least the first flow regulator mathematically related to a difference between a nominal battery charge determined from the received signals and the defined desired nominal charge of the battery.

49. The fuel cell system of claim 41, further comprising:
a control circuit coupled to receive signals corresponding to a voltage across the battery and to provide a control signal to at least the first flow regulator mathematically related to a difference between the voltage across the battery and a desired nominal voltage across the battery.

50. A fuel cell system for providing power to a load, comprising:
a fuel cell stack having a number of fuel cells;

a battery having a number of battery cells, portions of the battery interconnected with portions of the fuel cell stack such that the battery is electrically coupled in parallel across the fuel cell stack;

a reactant delivery system for delivering reactant to the fuel cells, the reactant delivery system including at least a first control element adjustable to control a partial pressure in a flow of a reactant to at least some of the fuel cells; and

a control circuit coupled to receive signals corresponding to an operating condition of the battery and configured to determine a deviation of the operating condition of the battery from a desired operational condition of the battery based on the received signals, the control circuit further coupled to control the at least first control element based on the determined deviation.

51. The fuel cell system of claim 50, further comprising:

a current sensor coupled to measure a flow of current into and out of the battery and to provide the measured flow of current to the control circuit as the signals corresponding to the operating condition of the battery.

52. The fuel cell system of claim 50, further comprising:

a voltage sensor coupled to measure a voltage across the battery and to provide the measured voltage to the control circuit as the signals corresponding to the operating condition of the battery.

53. A fuel cell system to power a load, the comprising:

means for supplying current to the load from at least one of a fuel cell stack and a battery electrically coupled in parallel with the fuel cell stack;

means for determining an operational condition of the battery;

means for determining an amount of deviation of the determined operational condition of the battery from a desired operational condition of the battery; and

means for adjusting a partial pressure of the reactant flow based on the determined amount of deviation for at least one reactant flow to at least a portion of the fuel cell stack.

54. The fuel cell system of claim 53 wherein the means for determining an amount of deviation of the determined operational condition of the battery from a desired operational condition of the battery includes an comparator and an integrator coupled to the comparator to integrate a difference between a defined desired nominal charge and current flows into and out of the battery over a period of time.

55. The fuel cell system of claim 53 wherein the means for determining an amount of deviation of the determined operational condition of the battery from a desired operational condition of the battery includes a voltage regulator coupled to compare a voltage across the battery to a defined desired nominal voltage.

56. The fuel cell system of claim 53 wherein the means for adjusting a partial pressure of the reactant flow based on the determined amount of deviation for at least one reactant flow to at least a portion of the fuel cell stack includes at least one flow regulator in a reactant flow.

57. The fuel cell system of claim 53, further comprising:
holding a pressure of the at least one reactant flow approximately constant while adjusting the partial pressure of the at least on reactant delivery system.

58. A fuel cell system for providing power to a load, comprising:
a voltage bus;
a first fuel cell stack having a number of fuel cells electrically couplable across the voltage bus;

a first battery having a number of battery cells electrically couplable in parallel across the first fuel cell stack on the voltage bus;

a first reactant delivery system for delivering reactant to the fuel cells of the first fuel cell stack, the first reactant delivery system including at least a first control element adjustable to control a partial pressure in a flow of a reactant to at least some of the fuel cells of the first fuel cell stack;

a first control circuit coupled to receive signals corresponding to an operating condition of the first battery and configured to determine a deviation of the operating condition of the first battery from a desired operational condition of the first battery based on the received signals, the first control circuit further coupled to control the at least first control element based on the determined deviation;

a second fuel cell stack having a number of fuel cells electrically couplable across the voltage bus;

a second battery having a number of battery cells electrically couplable in parallel across the second fuel cell stack on the voltage bus;

a second reactant delivery system for delivering reactant to the fuel cells of the second fuel cell stack, the second reactant delivery system including at least a second control element adjustable to control a partial pressure in a flow of a reactant to at least some of the fuel cells of the second fuel cell stack;

a second control circuit coupled to receive signals corresponding to an operating condition of the second battery and configured to determine a deviation of the operating condition of the second battery from a desired operational condition of the second battery based on the received signals, the second control circuit further coupled to control the at least second control element based on the determined deviation.

59. The fuel cell system of claim 58 wherein the second fuel cell stack and the second battery are electrical coupled in series with the first fuel cell stack and the first battery.

60. The fuel cell system of claim 58 wherein the second fuel cell stack and the second battery are electrical coupled in parallel with the first fuel cell stack and the first battery.

61. The fuel cell system of claim 58, further comprising:

a third fuel cell stack having a number of fuel cells electrically couplable across the voltage bus;

a third battery having a number of battery cells electrically couplable in parallel across the third fuel cell stack on the voltage bus;

a third reactant delivery system for delivering reactant to the fuel cells of the third fuel cell stack, the third reactant delivery system including at least a third control element adjustable to control a partial pressure in a flow of a reactant to at least some of the fuel cells of the third fuel cell stack;

a third control circuit coupled to receive signals corresponding to an operating condition of the third battery and configured to determine a deviation of the operating condition of the third battery from a desired operational condition of the third battery based on the received signals, the third control circuit further coupled to control the at least third control element based on the determined deviation.

62. The fuel cell system of claim 58, further comprising:

a third fuel cell stack having a number of fuel cells electrically couplable across the voltage bus;

a third battery having a number of battery cells electrically couplable in parallel across the third fuel cell stack on the voltage bus;

a third reactant delivery system for delivering reactant to the fuel cells of the third fuel cell stack, the third reactant delivery system including at least a third control element

adjustable to control a partial pressure in a flow of a reactant to at least some of the fuel cells of the third fuel cell stack;

a third control circuit coupled to receive signals corresponding to an operating condition of the third battery and configured to determine a deviation of the operating condition of the third battery from a desired operational condition of the third battery based on the received signals, the third control circuit further coupled to control the at least third control element based on the determined deviation, wherein the second fuel cell stack and the second battery are electrical coupled in series with the first fuel cell stack and the first battery, and with the third fuel cell stack and the third battery.

63. The fuel cell system of claim 58, further comprising:

a third fuel cell stack having a number of fuel cells electrically couplable across the voltage bus;

a third battery having a number of battery cells electrically couplable in parallel across the third fuel cell stack on the voltage bus;

a third reactant delivery system for delivering reactant to the fuel cells of the third fuel cell stack, the third reactant delivery system including at least a third control element adjustable to control a partial pressure in a flow of a reactant to at least some of the fuel cells of the third fuel cell stack;

a third control circuit coupled to receive signals corresponding to an operating condition of the third battery and configured to determine a deviation of the operating condition of the third battery from a desired operational condition of the third battery based on the received signals, the third control circuit further coupled to control the at least third control element based on the determined deviation, wherein the second fuel cell stack and the second battery are electrical coupled in series with the first fuel cell stack and the first battery, and wherein the third fuel cell stack and the third battery are electrically coupled in parallel with the first and the second fuel cell stack and the first and the second battery.